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HONEY LAKE ROBOTIC RANGE CLEARANCE OPERATIONS

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Final Report for 21 July 2003 – 29 September 2003

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14. ABSTRACT

This document is the final report of the Honey Lake Robotic Range Clearance research conducted by the Air Force Research Laboratory for the US Army Engineering and Support Center (USAESCH) in Huntsville, Alabama. The Honey Lake Robotic research project was conducted between 21 July 2003 and 29 September 2003 at the Honey Lake site on Sierra Army Depot, Herlong, CA. Approximately 2,600 acres of Honey Lake was contaminated with military munitions scrap and unexploded ordnance from open pit demolition operations. The first step in the transfer process of the contaminated area was a surface clearance of all unexploded ordnance and ordnance scrap metal. USAESCH requested AFRL/RXQF to perform research to determine if robotics would increase clearance production.

15. SUBJECT TERMS

Honey Lake, remediation, robotic, USAESCH, Sierra Army Depot, munitions, UXO, scrap, ARTS, power rake, surf rake, rock picker, magnet sweeper, clearance, disposal, tele-operated, surface

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TABLE OF CONTENTS

LIST OF FIGURES

Introduction

This document is the final report of the Honey Lake Robotic Range Clearance research conducted by the Air Force Research Laboratory for the US Army Engineering and Support Center (USAESCH) in Huntsville, Alabama. The Honey Lake Robotic research project was conducted between 21 July 2003 and 29 September 2003 at the Honey Lake site on Sierra Army Depot, Herlong, CA.

Background

The Air Force Research Laboratory, Force Protection Branch, Robotics Research and Development Team (AFRL/RXQF Robotics) is responsible for research in the areas of robotic equipment and methods for ordnance clearance operations. The USAESCH requested the AFRL/RXQF Robotics Team to perform a technology demonstration project for an ongoing clearance operation at Sierra Army Depot, CA.

Sierra Army Depot was responsible for returning the 60,000-acre Honey Lake parcel to the State of California. Honey Lake is a dry mountain plain lake that was used for military munitions disposal by Sierra Army Depot. Approximately 2,600 acres of Honey Lake were contaminated with military munitions scrap and unexploded ordnance from open pit demolition operations. Step one in the transfer process of the contaminated 2,600 acres was a surface clearance of all unexploded ordnance and ordnance scrap metal. USAESCH contracted with ATI Incorporated to perform this surface clearance. In addition, USAESCH requested AFRL/RXQF to perform research to determine if robotics would increase clearance production.

Within two weeks of request from the USAESCH, AFRL/RXQF Robotics deployed to Honey Lake with existing robotic equipment and tools to assist in the surface clearance operation. AFRL/RXQF Robotics used the All-Purpose Robotic Transport System (ARTS) system with a Barber Surf Rake and Harley Rock Picker to remove the majority of scrap items from the lakebed surface. After the robotic system completed a grid, the unexploded ordnance (UXO) contractor personnel would remove any remaining items per their standard procedures.

Methods

AFRL/RXQF Robotics deployed to Honey Lake for an initial two-week evaluation phase. Due to the success of the first two weeks operations, the demonstration was extended by the USAESCH through the end of September 2003. Initially, AFRL/RXQF Robotics brought one ARTS, a Barber Surf Rake, a Harley Power Rake, a Shield's Permanent Magnet Sweeper, and a Mobile Command Center for evaluation. By the end of the project, AFRL/RXQF Robotics added a 2nd ARTS and a Harley Rock Picker.

The ARTS (Fig. 1) is a tele-operated system that is remotely controlled through a radio link by the system operator. The ARTS is capable of up to 3 miles operating range with line-of-sight antenna limitations. The ARTS is a fielded Air Force Robotic System used for explosive ordnance disposal, see attached ARTS fact sheet (Appendix A). The ARTS was

operated out of the AFRL mobile command center (Figs. 2, 3). The ARTS system requires only one operator, but a minimum crew of two is required at all times for safety reasons.

Figure 1 – ARTS Emblem

Figure 2 – Command Post

Figure 3 – ARTS Operator

Figure 4 – ARTS With Surf Rake

The primary tool used during the Honey Lake clean-up operations was the Barber Surf Rake model 600 HD (Fig. 4), see Appendix B for specifications. The surf rake was powered by the hydraulic and PTO systems on the ARTS and was towed behind the ARTS using a three-point hitch adapter. The surf rake operates by using a rotating belt of tines to scrape the ground surface and pick up any objects larger than the tine-to-tine gap (1.5-2”). The picked-up material is carried up the tine belt and deposited in the rear hopper.

The surf rake can be adjusted to control the tine penetration depth and tine belt speed. The best performance was obtained with a tine penetration depth between ½” and 1”, a relatively fast tine belt speed (flow control setting = 9), and approximately 2.5 mph travel speed. At these settings, the surf rake process picked up about 85% of the surface scrap. The surf rake picked up a small amount of objects less than 1.5” in size. The surf rake picked up almost all medium size objects 1.5” to 16” in size. The surf rake was able to pick up some of the very large objects, full 155mm shells and similar. However, successful capture of a full 155mm shell was a hit and miss process that damaged many of the tines and was not consistent. By the end of the project we modified the process to go over or around full shells and other very large objects to avoid equipment damage. The surf rake process was very successful in covering the most acreage per hour and picking up the majority of scrap items.

The Harley Power Rake was briefly evaluated at the start of the project (Fig. 5). The power rake does not have a collection hopper like the surf rake. It works by churning up the soil and scrap items and collecting the large items in front of the rake. The soil and smaller items are passed between a separator plate and the digging roller. The power rake was effective at collecting the very large items like full 155mm shells, but not the smaller items. Also, the power rake did not collect items that were long and thin because they would pass through the roller gap in the thin direction. The aim of the Honey Lake project was for a surface clearance only. This was a problem for the power rake because to work it must dig at least 1"-2" deep in the soil. For this reason and the poor performance collecting the majority of the scrap items, the power rake use was terminated. For specifications see Appendix C.

Figure 5 – Power Rake

Figure 6 – Permanent Magnet

A Shields Model 5000 magnetic sweeper was tested for picking up frag scrap items (Fig. 6). The magnet is a permanent style magnet that requires no electricity for operation. The magnet is always "on". It uses a lever mechanism to move the magnet away from a collection plate to drop collected items. The magnet can be mounted on a trailer or carried on a fork assembly. For the evaluation, the magnet was mounted on the ARTS fork assembly and the discharge lever was automated with an electric actuator for remote operation. See Appendix D for specifications.

The performance of the magnet system was insufficient to pick up most scrap items. The magnet was used in areas previously cleaned by the surf rake as well as in untouched areas. The main goal was to pick up the smaller ferrous items that the surf rake left behind. The magnet system picked up a very small amount of the ferrous scrap items from cleaned and uncleaned areas. Numerous attempts and configuration changes produced no decent results with the magnet. In the end, either the rusted metal had lost too much of its magnetic properties or the magnet is just too weak for this type of operation. The magnet was the strongest system available with the short lead-time for this operation. In addition, USAESCH geophysicists monitored a test strip at the site to determine if the magnet induced residual magnetism into the soil that would inhibit future geophysical investigations at the site. No induced magnetism was encountered. Future investigations are planned to focus on electromagnet systems.

Halfway through the project, the decision was made to bring out a 2nd ARTS robot and to procure another type of collection equipment for evaluation. The Harley Rock Picker (Figs. 7 and 8) was selected due to its availability, capabilities, and compatibility with the ARTS. See Appendix E for specifications. The manufacturer had a rock picker in stock for immediate shipment when needed and the ARTS could run the Harley Rock Picker using its PTO and auxiliary hydraulics. Many of the alternative systems were too large for the ARTS to operate. The rock picker can remove materials from a previously windrowed pile or straight from the ground surface. The rock picker uses a rotating drum with a screen to break up the soil and remove items larger than the selected screen size. The screens come in a variety of sizes from below 1" and up. The remaining large items are conveyed into a collection hopper.

For the Honey Lake project, the rock picker was used in the straight picking mode to directly remove the scrap items from the surface. The rock picker was setup with extension guides that enabled it to cover a 5' wide path from ¾" to 1" deep. The rock picker performed the best at picking up the most scrap items. It picked up approximately 95% of the frag & scrap items on the surface. It also made the cleanest scrap piles with the least amount of dirt. This was due to the rotating drum action breaking up the dirt so it was not collected in the hopper. However, the rock picker only operated at about half the speed of the surf rake. This was due to the limited power available from the ARTS. If used with a more powerful system the speed could be increased.

Figure 7 – Rock Picker

Figure 8 – ARTS with Rock Picker

AFRL/RXQF Robotics also evaluated several innovative concepts during this demonstration including: Night Operations, Simultaneous Robotic Operations, and Extended Operations. Robotic night operations (Fig. 9) were conducted during 6 of the 8 weeks to allow UXO contractor personnel to operate on the site during daylight hours. The standard ARTS light system was augmented with 500watt halogen lights powered by a small generator and 12v lights added for auxiliary views of the collection hopper and operating equipment. The lights provided sufficient light for all operations including running the surf rake, rock picker, dumping the collected materials, and driving to and from the command post. The standard ARTS color cameras were used with no modifications. Low light cameras were considered but were not pursued due to the time constraints involved with the project.

The night operations were very successful with no performance impact to the robotic clearance efficiency due to operating during night hours. The light system provided plenty of light to perform all robotic operations including monitoring of the material processing and collection. Large scrap items and obstacles were easily seen, and navigation by following the lanes was possible.

Figure 9 – Operator Night View

Figure 10 – ARTS Working in Sandstorm

Simultaneous Robotic Operations were conducted during 2 weeks of the demonstration. The 1st ARTS with the surf rake and the 2nd ARTS with the rock picker were operated at the same time on different grids for increased productivity. The video transmission radios were set up on different frequencies to avoid interference. The current ARTS video radios only support 3 channels; therefore the practical limit is 3 systems operating within about a 5-mile radius. There were no issues with interference or other problems associated with multiple robotic operations.

The ARTS demonstrated the ability to operate in an austere environment for an extended period of time. Over 260 robotic operating hours were accumulated during the technology demonstration. The systems were stored out in the environment during the entire project with no shelter. The ARTS and equipment were subject to different weather conditions including: severe heat (120° F), driving sandstorms (Fig. 10), and heavy rain. The electrical and hydraulic systems did not overheat during operations in the extremely hot 120° F weather. Also, the electrical systems are insulated and have active thermoelectric coolers to maintain operating temperature.

Support and maintenance of the equipment was performed at the remote location. The ARTS required daily fueling, lubrication, and inspection. The ARTS system experienced three component failures during operations. One exterior hydraulic supply line developed a leak, one internal hydraulic PTO pump line ruptured, and the operator joystick broke. The first hydraulic line was replaced within hours and operations resumed. The internal line rupture occurred during the last week of operation. The line was not field serviceable and shut down all operations with the 1st ARTS due to the limited time remaining on the project. The 2nd ARTS was used to complete the project alone. The joystick failed due to a worn out actuator switch. This switch is used every time the robot is started and stopped and simply wore out.

The surf rake and rock picker both had a few maintenance issues. The surf rake PTO shaft extension broke twice in the first two weeks. This was replaced with a heavily reinforced shaft extension that lasted for the duration of the project with no sign of failure. A surf rake hydraulic line developed a small leak and was replaced. Finally, both the surf rake and rock picker experienced flat tires. The surf rake had three flat tires before the standard tires were replaced with foam filled tires. The rock picker had one flat tire and it was plugged and re-inflated in the field.

Results

AFRL's robotic systems operated for a period of 8 weeks on the Honey Lake site at Sierra Army Depot from July 21 through September 29, 2003. During the demonstration, the robots operated for 261 hours in 34 days of operations. There were 5 unplanned days with no operations due to maintenance and weather. The robotic systems removed an estimated 95,600lbs of scrap materials from 19-grids (285 acres) with an average production rate of 1.02 acres per hour and a maximum rate of 1.86 hours achieved. The learning curve (Fig. 11) shows the continuous improvement in operating efficiency. A summary of the operator log is shown in Figure 12. The complete operator log is included in Appendix F.

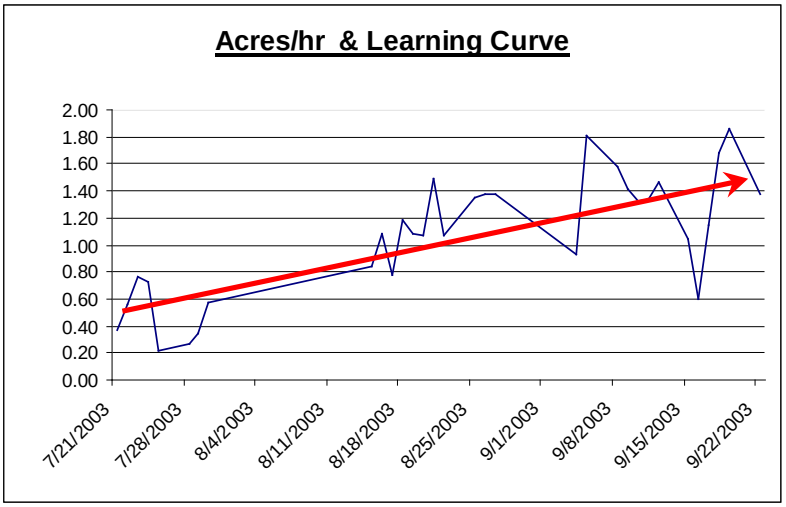


Figure 11 – Acres/hr & Learning Curve

Quick Facts: 261 operating hours, 285 acres cleared, 95,600 lbs scrap, Average 1.02 acres/hr

Date	Notes:	Hours	Acres	Acres/hr	Total acres	Lbs scrap (est.)	Total scrap
7/21/2003	Setup with Power Rake & test	2.5	0	0	0	0	0
7/22/2003	Initial Setup, Small magnet tests	7.1	2.60	0.37	2.60	1100	1100
7/23/2003	PTO shaft Broke	0.5	0.28	0.56	2.88	300	1400
7/24/2003	Hydraulic Line broke	2.4	1.67	0.76	4.56	500	1900
7/25/2003		4.6	3.35	0.73	7.90	1800	3700
7/28/2003	Flat Tire	6	1.30	0.22	9.20	700	4400
7/29/2003		4.1	1.12	0.27	10.32	700	5000
7/30/2003	Down to get large magnet, quick test that evening	0	0.00	0.00	10.32	0	5000
8/15/2003	Start of night operations	9.8	3.35	0.34	13.67	600	5700
8/16/2003		10.8	6.14	0.57	19.80	2200	7900
8/17/2003		10.5	7.81	0.74	27.61	2800	10700
8/18/2003		8	6.69	0.84	34.31	2400	13100
8/19/2003		8	8.70	1.09	43.01	3000	16100
8/20/2003	Surf Rake Flat tire	10	7.81	0.78	50.82	2800	18900
8/21/2003		8.5	10.04	1.18	60.86	3400	22300
8/22/2003	Down - Rain	0	0	0	60.86	0	22300
8/25/2003		8.5	9.20	1.08	70.06	3100	25400
8/26/2003		7.8	8.37	1.07	78.43	2500	27900
8/27/2003		7.5	11.16	1.49	89.59	3800	31700
9/4/2003	Late Start - Weather	6.5	6.97	1.07	96.56	2800	34500
9/5/2003		8.7	11.77	1.35	108.33	4000	38500
9/8/2003		8.5	11.71	1.38	120.04	4000	42500
9/9/2003		8.1	11.16	1.38	131.20	3800	46300
9/10/2003	Joystick Controller Broke	7.5	6.97	0.93	138.17	3300	49600
9/11/2003	Down waiting on Joystick	0	0	0	138.17	0	49600
9/12/2003		8.5	15.34	1.81	297.26	3400	53000
9/15/2003		8.5	13.48	1.59	166.99	2900	55900
9/16/2003		8.3	11.71	1.41	178.71	2600	58500
9/17/2003		8.6	11.44	1.33	190.14	2500	61000
9/18/2003		8.7	11.62	1.34	201.76	2600	63600
9/19/2003	Began using Rock Picker	8.9	13.02	1.46	214.78	2800	66400
9/22/2003	Rock Picker & Surf Rake	7.5	7.81	1.04	222.59	3200	69600
9/23/2003	1st ARTS PTO pump broken	8.5	5.09	0.60	227.68	2700	72300
9/24/2003	Switch back to Surf Rake only	8.3	9.48	1.14	237.17	3600	75900
9/25/2003		8.5	14.28	1.68	251.45	5400	81300
9/26/2003		9.4	17.52	1.86	268.96	6200	87500
9/29/2003	Operations complete	11.1	15.25	1.37	284.21	8100	95600

Figure 12 - AFRL Robotics Team - Honey Lake Project Summary

Prior to the introduction of the robotic systems, the Honey Lake site was being cleared using only manual methods. The clearance was performed by teams of UXO technicians that would walk each grid and pick up all scrap materials larger than a "bottle cap." The technicians would evaluate the items and if determined to be inert scrap would collect them in a bucket. The amount of time required to manually clear a grid depended on the number of technicians working a grid and the relative amount of scrap in the grid. Depending on the location of the grid, the amount of scrap varied from widely scattered to very dense with as little as 1 lb of scrap per grid up to 34,620 lbs on the worst grid Typically a 20 person team would take about 3 weeks to clear an average grid. The use of robotic systems decreased the average time for manual clearance of each grid from approximately 3 weeks to 1 week.

Scrap collection performance was continuously increased during the demonstration project. Initially, the collected scrap piles had a large amount of dirt mixed in with the scrap items. Through consistent process optimization, the amount of dirt in the piles was significantly reduced (Figs. 13, 14).

Figure 13 – Scrap Pile Start of Project

Figure 14 – Scrap Pile End of Project

To reduce the amount of dirt in the scrap piles, the surf rake was modified to have a mesh bottom hopper so the maximum amount of loose dirt could pass through. Although this led to some small scrap items passing through the mess screen, the significant reduction in the amount of dirt in the piles was preferred. The operational settings of the surf rake were optimized to provide the best scrap collection versus dirt and time. The best results were obtained using the settings mentioned in the previous section. To minimize dirt contamination, the surf rake operating depth had to be closely monitored to maintain the optimum performance. In certain soft soil conditions or if the surf rake was allowed to drift down the system would collect too much dirt and would have to be raised using the hydraulic system. This could be adjusted "on the fly" while remotely operating the vehicle.

The Harley Rock Picker provided superior performance in both picking up more scrap items and leaving cleaner scrap piles. However, as previously mentioned the rock picker was significantly slower than the surf rake in the amount of acres covered per hour.

Costs:

A breakdown of major equipment suppliers and system costs are shown in Appendix G. The project cost AFRL $182,333.48. USAESCH provided $170,000 for the project with the Joint Robotics Program funding the remaining $12,333.48. The majority of the costs were for technician and engineer wages - $118,366.15. Travel and per diem cost were $35,073.56. Operating expenses and supplies were $18,137.29, and shipping charges were $10,756.47. This equates to $640 per acre for the robotic clearance. These costs can be greatly reduced by utilizing trained contractor personnel, instead of AFRL's technicians and engineers, to operate the robotic equipment. Using contractor personnel should also eliminate a large portion of the travel costs. A reasonable estimate for production clearance with contractor personnel operating the robots is around $500 per acre. This level of robotic clearance would still require a secondary sweep by UXO technicians to retrieve missed items and inspect the grid. A financial breakdown by month is included in Appendix H.

Conclusions & Recommendations:

The results of the Honey Lake Robotics Range Clearance demonstration have shown that robotic systems are a safe and efficient alternative to manual clearance methods at heavily contaminated sites. The robotic systems operated for 8 weeks in an austere environment where they were exposed to a wide range of environmental conditions from extreme heat, thunderstorms, and even sandstorms. The systems were maintained in the field with daily preventative maintenance, servicing, and some heavy maintenance. The mechanized equipment evaluated proved to be more efficient for picking up the majority of the scrap items compared to manual clearance methods. The only mechanized alternative to robotic clearance is to use manually operated armored equipment. This is not only a significant cost to procure, but more importantly exposes UXO technicians to a high risk from explosive hazards.

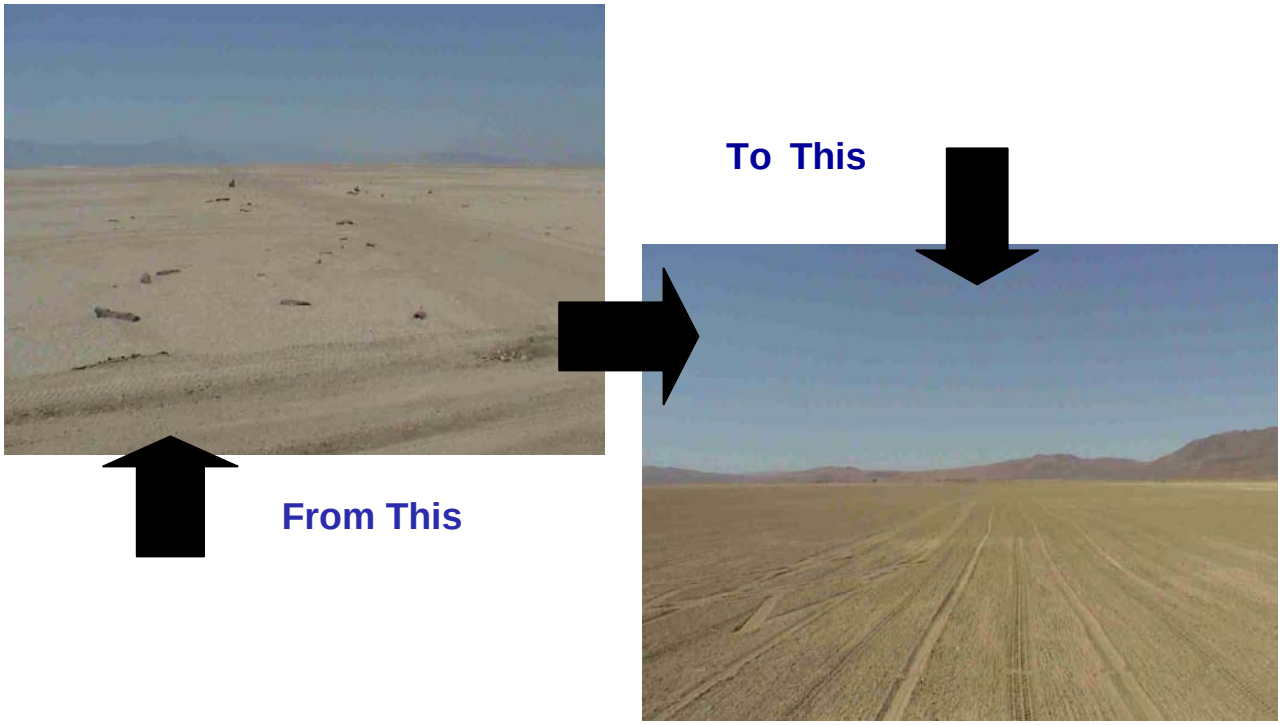
The most significant result of this project was the demonstration of night robotic operations capability. Traditionally, range operations are only conducted during daylight hours for the safety of the UXO technicians. Robotic systems are not limited to daylight operations for personnel safety. This opens up a new opportunity for clearance operations, by combining manual clearance with the robotic systems to maximize the available working time on the site. The UXO technicians used the daylight hours to conduct their operations and then the robotic systems operated during the evening and night hours. This system allowed the clearance time to be doubled from 8 to 16 hours per day. If a third crew was available, 24 hour continuous operations were possible.

Another significant accomplishment of the night operations was the ability to maintain the production rate during night operations. There was no difference in the amount of acres/hr covered during night operations versus daylight operations. This further shows the utility and functionality of using robotic systems for UXO clearance operations.

The following are AFRL/RXQF Robotics Team's recommendations for future use of robotic and mechanized systems for UXO clearance operations.

- Support contractors should be required to evaluate robotic and mechanized systems for inclusion in project proposals. The technology exists today for off-the-shelf system capable of performing many of the clearance tasks at a significant cost and time savings compared to manual methods. The associated increase in safety is immeasurable.
- The use of robotic systems should be designed into the process during the initial project planning. This will allow for the optimal types of equipment and processes to be selected for a site's specific needs.
- Further development should be continued in the area of mechanized UXO retrieval and processing. The technology currently exists to provide mechanized solutions to a majority of the UXO clearance issues from excavation through processing and sorting. The goal should be to provide a remotely operated processing system specifically for the type of UXO and ordnance expected from a site.
- Further development should be continued in the area of magnetic retrieval systems. Electromagnet systems exist which should provide superior performance for the collection of ferrous scrap particles of all sizes at a significant cost savings compared to manual methods.

FINAL RESULTS



Appendix A

ALL-Purpose Remote Transport System
ARTS

US Air Force Research Laboratory, Tyndall Air Force Base, Florida

MISSION: The All-Purpose Remote Transport System (ARTS) provides Air Force EOD personnel with a multi-purpose system. It provides a teleoperated system that can locate, remove and neutralize unexploded ordnance (UXO) and improvised explosive devices (IED). The ARTS has served as a platform for integration of advanced payloads to meet real world missions.

The ARTS is deployed to assist EOD technicians in the clearance of unexploded ordnance on bombing ranges. Before ARTS, this dangerous mission was performed by EOD technicians combing the bombing range, identifying each UXO, and then destroying each one in place. The ARTS with its mounted blade can push UXO to the side in rows that allow for safe neutralization later. With the bombing of Khobar Towers, the Air Force had an immediate requirement for force protection. Integrating a 90mm water cannon on the ARTS, the system fires a water filled projectile that can penetrate a vehicle disrupting the IED.

REQUIREMENTS DOCUMENT: The Operational Requirements Document for ARTS was approved by the Air Force (ORD CAF (USN) 014-93 I/II-A). Supporting documentation is found in Mission Needs Statements for Active Range Clearance and Enhanced Force Protection Capabilities.**PROGRAM STATUS:** The Air Force Research Laboratory (AFRL), Material and Manufacturing Directorate, Airbase Technologies Division, Force Protection Branch (AFRL\RXQF) at Tyndall AFB, FL is the material developer for ARTS.

The ARTS completed Operational Testing in December 96 at Nellis AFB where it windrowed hundreds of BLU 97A/B cluster munitions, withstanding six detonations. Before the system could enter production, prototype systems with a 90mm cannon were deployed to Kuwait and Saudi Arabia to combat terrorism.

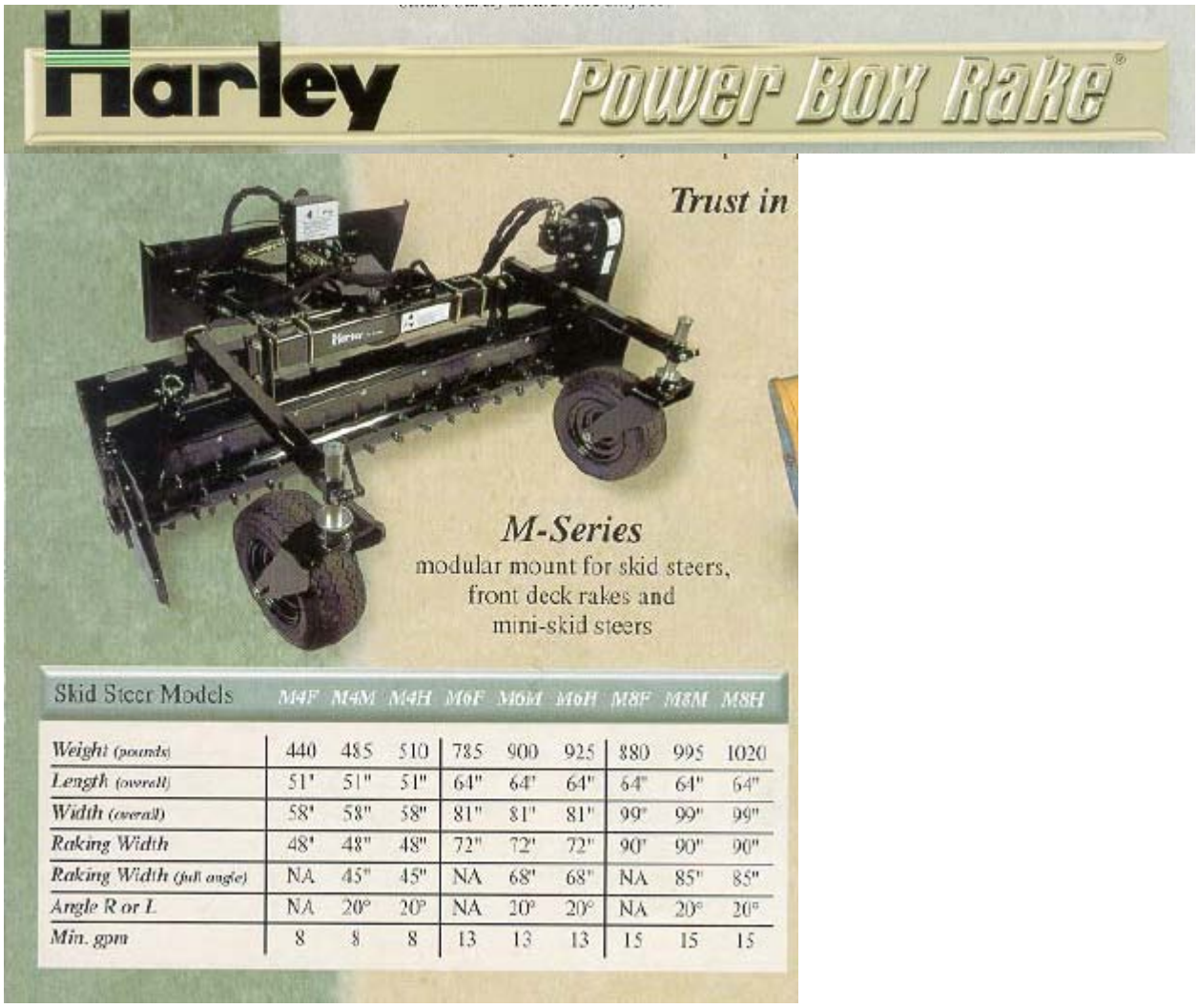
As EOD technicians become more comfortable with ARTS. They have requested that AFRL explore other means to aid in the neutralization of UXO, IED's or Weapons of Mass Destruction. In FY 01, AFRL integrated robotic arms on the ARTS for the Bureau of Alcohol, Tobacco and Firearms and the Air Force EOD unit at Nellis AFB, NV. In addition, for Nellis AFB, a water cutter was integrated on an ARTS to allow EOD personnel to cut into objects such as doors to better identify or locate an IED.

Appendix B

SURF RAKE Specifications

MODELS:	600HD
DIMENSIONS:	H: 7'6" L: 13'1" W: 7'8"
WEIGHT:	Approximately 3800 lbs
CLEANING WIDTH:	7 feet (6 feet deep cleaning)
CLEANING DEPTH:	Adjustable to 6"
OPERATING SPEEDS:	1.0 to 15.0 miles per hour
DEBRIS REMOVED:	Broken glass, plastic, syringes, cigarette butts, pop-tops, straws, cans, tar balls, stones 3/8" to 6" in diameter, sea grass, seaweed, fish, small pieces of wood.
PERFORMANCE:	Cleans 2 to 7 acres per hour
HOPPER:	2 cubic yards (3800 lbs cap)
DUMP HEIGHT:	8 feet / 9 Feet Clearance
TIRES:	36 x 13.5 x 15 high flotation design
CONVEYOR:	Of bar flight type, covered with continuous 6' wide belt, with stainless steel spring tines mounted on it.
HYDRAULIC DRIVE:	Completely sealed and protected by the full flow filter. Large capacity spline mounted pump, hydraulic motor, flow control, and built-in overflow protection.
HYDRAULIC FLOW:	12 gallons per minute
HYDRAULIC CAP:	15 gallons
CYLINDERS:	Lift 3½ x18" single acting Trip 2' x 5' single acting
PAINT:	Dupont IMRON® Polyurethane enamel
TRACTOR	60 PTO horsepower 4-wheel drive agricultural type tractor with 30" rear wheels.
OTHER TRACTOR REQUIREMENTS:	540 RPM rear PTO, 3-point hitch and depending on model and options, up to 3 remote hydraulic valves with raise, hold, and float positions. Larger or smaller tractors may be used depending on beach conditions.

Appendix C



Skid Steer Models	M4F	M4M	M4H	M6F	M6M	M6H	M8F	M8M	M8H
Weight (pounds)	440	485	510	785	900	925	880	995	1020
Length (overall)	51"	51"	51"	64"	64"	64"	64"	64"	64"
Width (overall)	58"	58"	58"	81"	81"	81"	99"	99"	99"
Raking Width	48"	48"	48"	72"	72"	72"	90"	90"	90"
Raking Width (full angle)	NA	45"	45"	NA	68"	68"	NA	85"	85"
Angle R or L	NA	20°	20°	NA	20°	20°	NA	20°	20°
Min. gpm	8	8	8	13	13	13	15	15	15

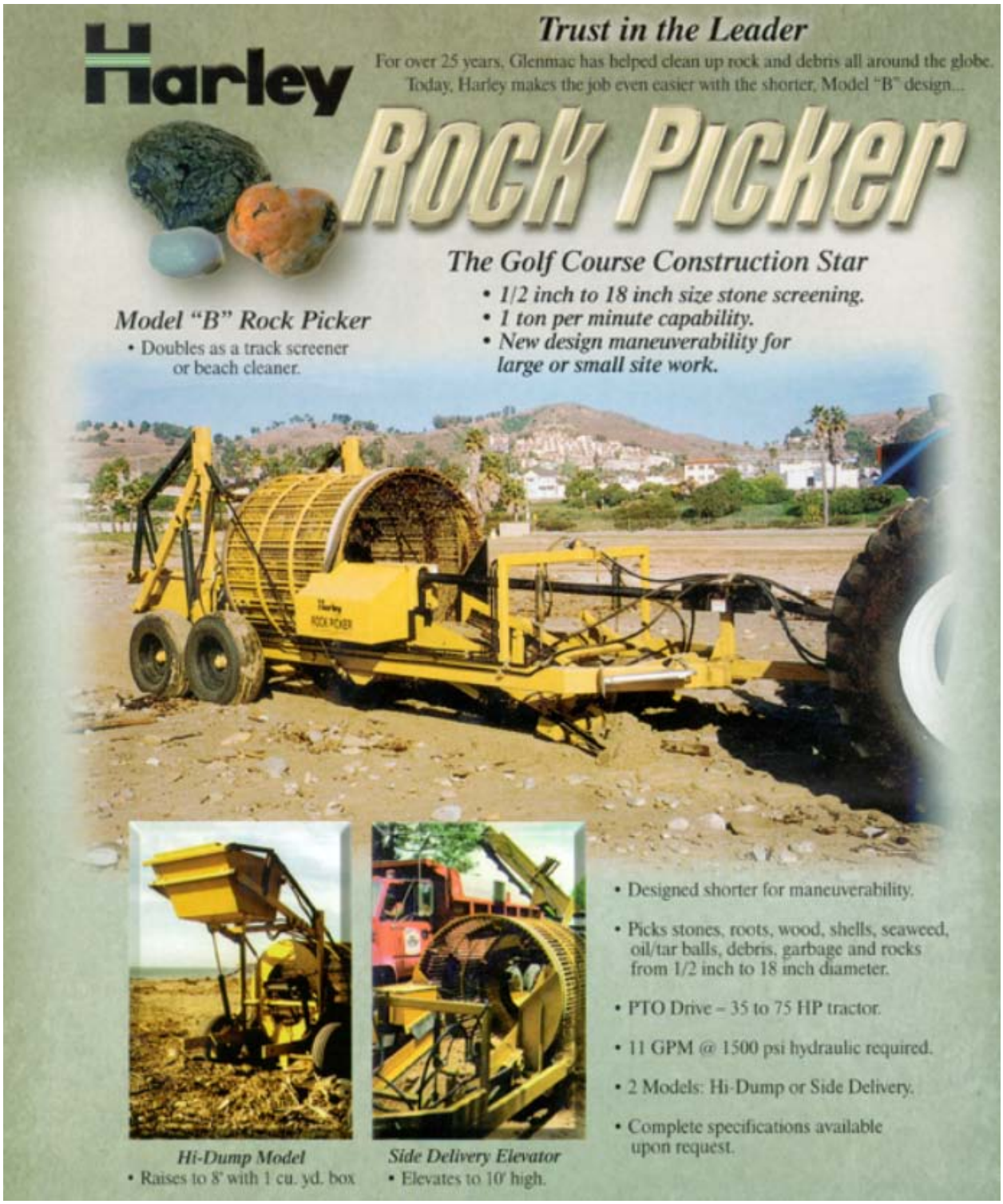
Appendix D

MKS5000R/A Road/Airfield Magnetic Sweeper

Three sweepers can be towed side-by-side with one towing vehicle for up to 24 feet of magnetic sweeping width.

- The ultimate magnetic sweeper for large areas such as airfield runways, municipal parking lots, state and county roads, etc.
- Magnet assembly can be trailer-mounted (as shown), bumper mounted, or carried by a forklift.
- Super-power magnets enclosed in a heavy gauge welded housing are height adjustable to provide sweeping clearance from 2" to 6".
- A simple pull on the gas spring-assisted release lever will release all attracted material and holds the magnet open while the operator moves the sweeper away from the debris pile!
- With optional Extended Width Trailer, three sweepers can be towed side-by-side with one towing vehicle.
- Equipped with 4.8 x 8" pneumatic tires, safety reflectors, safety chain, and your choice of coupling attachments.
- Trailer constructed of heavy steel members for long lasting performance and durability.
- Standard sweeping widths of 60" to 96"
- Unconditional Product Performance Guarantee

Appendix E


Harley
Trust in the Leader
For over 25 years, Glenmac has helped clean up rock and debris all around the globe. Today, Harley makes the job even easier with the shorter, Model "B" design...
ROCK PICKER
The Golf Course Construction Star
• 1/2 inch to 18 inch size stone screening.
• 1 ton per minute capability.
• New design maneuverability for large or small site work.
Model "B" Rock Picker
• Doubles as a track screener or beach cleaner.
Hi-Dump Model
• Raises to 8' with 1 cu. yd. box
Side Delivery Elevator
• Elevates to 10' high.
• Designed shorter for maneuverability.
• Picks stones, roots, wood, shells, seaweed, oil/tar balls, debris, garbage and rocks from 1/2 inch to 18 inch diameter.
• PTO Drive – 35 to 75 HP tractor.
• 11 GPM @ 1500 psi hydraulic required.
• 2 Models: Hi-Dump or Side Delivery.
• Complete specifications available upon request.

Appendix F

Honey Lake Log
Complete:

Date	Start Time	Stop Time	Hours	Configuration	Results	# Dumps	Notes:
7/21/2003	1300	1530	2.5	Power Rake Only	1 Path up and back		Good for large pieces but not smaller or fragments - general setup and trial
7/22/2003	805	1510	7.1	Surf Rake Only	11 up and back trips total - 140 wide x 830 long	11	Check results and setup. Lost communication - collection bin blocked antennas during dump - make sure not to block antennas while dumping. Round trip time 26min 30 sec - Up & Back patterns - PTO shaft extension for surf rake broken temp 115F
7/23/2003	830	900	0.5	Surf Rake Only	3 passes@830 Ft	3	Changed to Zamboni pattern and increased speed - PTO shaft broke again. Spent all day getting fixed.
7/24/2003	713	939	2.2	Surf Rake Only	9 passes - 5 dumps	5	Stopped to allow Army Corp inspection. Completed zamboni section. Stop to change over to magnet/power rake. Found ruptured hydraulic line during recovery inspection. Looks like another long day in the dessert.
7/24/2003							Had to use power rake hydraulic line to fix ARTS. Setup with magnet only left command post at 1241.
7/24/2003	1253	1302	0.2	Small Magnet Only	30ft pass		Stop to check results - release force too great for, did OK but need a bigger magnet. Pulled steel out of piles. Shut down @ 1347 to get fuel and do maintenance.
7/25/2003	721	1210	4.6	Surf Rake Only	18 dumps	18	Speed 4 mins for 830 ft , 1min 50sec for side passes = 2.3 mph. Stop to check results, 2.3 mph = approx 1.2 acres/hr
7/28/2003	8:45	2:45	6	Surf Rake Only	7 dumps	7	After setting up we started with surf rake and got a piece of frag in the tire. We got the tire fixed and got a spare and were running again at 1:00
7/28/2003							We installed the other tire on the surf rake and we were able to sweep with very little dirt accumulating in the hopper which allowed us to make three passes except in heavy areas.
7/29/2003	6:50	11:00	4.1	Surf Rake Only	6 dumps	6	We achieved the clearance that they needed with just two passes with the surf rake.
7/30/2003							Bill is in route to pick up the large magnet
8/14/2003	15:30	23:00	7.5	Surf Rake Only	1 dump	1	On 8/12/2003 and 8/13/2003 had welder cut bottom and edges out of hopper and had screen installed. Note: The weight we cut out made the hopper flip too far and cut both tires on surf rake. We only completed one pass. Left area at 11pm

8/15/2003	15:00	0:45	9.8	Surf Rake Only	6 dumps	6	Made 9 passes, installed two more lights on rear of ARTS to improve night driving. Cleared area 60' wide 3 grids long. The grids are p-33-34-35 going from north to south as per Roland, running with 3/4 screen in hopper. Talked to Roland at 1 am and let him know everything ran good. He asked us to work longer in the grids .
8/16/2003	14:00	0:45	10.8	Surf Rake Only	22 dumps	22	Changed out screen from 3/4 to 1" square, still going north to south, still getting a lot of dirt in dump piles. Installed 1 1/4" screen in bottom. Will install on sides in morning. Unit running well. We put two chains on rear as marker drags so we can see where we have been. It takes about 11 min to cross three grids.
8/17/2003	14:00	0:29	10.5	Surf Rake Only	28 dumps	28	Changed out side screens to 1 1/4". This seems to be letting a lot of dirt out. The one pass piles are smaller than they have been with less dirt and still picking a large amount of frag. Speed up ARTS to 7 min a pass still picking up frag at same rate. 11pm increased tine speed on rake. Noticed that a hydraulic line has a small leak; it had been smashed from before. Will replace tomorrow .
8/18/2003	16:20	0:17	8	Surf Rake Only	24 dumps	24	Installed hydraulic hose on rake. Started on other end of grid due to earth tech area. Before dark ran rack over large piles of frag and dirt to clean them up. It worked real well. This will leave one pile on each end. Completed 120' of grid on the west end. This included to on the east end .
8/19/2003	16:30	0:20	8	Surf Rake Only	30 dumps	30	Cleaned 1st weeks piles until 1650. Did a very good job removing most of the dirt. Installed 110v generator and 500watt halogen light. Rate is 4 passes per hour, 12min 50 sec per pass with dump. Approx 4 days per 3 grids. 156' completed tonight. 141' left for these grids.
8/20/2003	15:30	1:31	10	Surf Rake Only	28 dumps	28	Arrived at site at 14:10 to service ARTS so we could start at 15:30 on time. 17:20 left rear tire went flat, changed out tire and resumed ops. 20:00 fueled ARTS and turned on lights. Note: a large part of the tines are getting bent up; will order some more. Note: small amount of rain in area. Finished grids p33, 34,35, will start new grids tomorrow. Found two large pit areas that go very deep with large items

8/21/2003	15:45	0:12	8.5	Surf Rake Only	34 dumps	34	Arrived at site at 13:30, went to Susanville to pay welder. Serviced ARTS and surf rake. Ordered 100 tines for rake; they should be here next week. Started on grids o-33, 34,35. Note: we are going over grid 34 again. This is the one done during the first two weeks. Will check on having tires foam filled. Completed 180' wide path.
8/22/2003				Surf Rake Only	1 dump	1	Tried to clear an area but the rake picked up to much mud. Went back to the room. Were off 23/24th. Took truck to have it serviced on the 23rd.
8/25/2003	15:30	0:00	8.5	Surf Rake Only	30 dumps	30	Arrived at 1400. Went down range, turned lights on and fueled ARTS at 20:00 night. Went very well. No break downs. Left grid at 00:30, returned to command post. Completed 165' wide path.
8/26/2003	16:30	0:16	7.8	Surf Rake Only	25dumps	25	Arrived at site at 14:00. Went to see if new tines were in; they are not. Will put new tires on tomorrow. Cleaned 12 piles at south west corner of p-34, made 5 piles. These were piles from the first ops full of dirt; now they are clean. Cleared 150' wide path.
8/27/2003	16:20	11:45	7.5	Surf Rake Only	38 dumps	38	Started on south end going north; found area earth tech dug and piled our piles with dirt. 19:30 fueled ARTS and turned on lights. Brought ARTS back at 23:30 to load out for weekend; completed 200'.
9/4/2003	18:00	0:25	6.5	Surf Rake Only	28 dumps	28	Replaced 77 tines on surf rake, re-welded three-point hitch mount pin. Got late start due to severe weather. Completed grids o-33, 34, 35. Note: ARTS is using a lot more fuel with foam tires. Completed 125'.
9/5/2003	15:30	0:12	8.7	Surf Rake Only	40 dumps	40	Started grids n-33-34-35. Had to go down range to remove frag from skirt of rake; it was digging in. Went out on grid to fuel ARTS and turn on lights 21:38. Completed 40 passes; total of 211' completed. UXO tech found two rounds with h.e. during scrap pile inspection.
9/8/2003	15:45	0:16	8.5	Surf Rake Only	40 dumps	40	Was on the grid at 15:20, could not start till 15:45 because Earth Tech & ATI supervisors came by and looked at robot. Lowered the front of the rake. Buy three washers on each side so the tines would pick up better. Will check progress at the end of the night. Completed 210'. Note: piles are getting smaller but grid is cleaner in areas.
9/9/2003	15:49	0:00	8.1	Surf Rake Only	38 dumps	38	Received rock piker from TMO. Got late start due to picking up equipment and wind. We are not picking up much for frag. The end of these grids are pretty

							clean. Completed 200'.
9/10/2003	15:20	22:45	7.5	Surf Rake Only	33 dumps	33	Changed bottom and rear side screens 1.25 to 1" to see if we can pick up smaller frag. Controller went out. Tried the spare and the propel mode switch is bad. Completed 125'.
9/12/2003	15:30	0:00	8.5	Surf Rake Only	14 dumps grids n-33-34-35	14	Received new joy sticks. ARTS works well. Replaced 22 tines on rake. Completed n-33-34-35. Completed 100' on the three. Moved to grids m-30-31-32-33-34. This gives us 5 grids in a row. Completed 20 dumps, total of 105'.
						20	
9/15/2003	15:20	0:00	8.5	Surf Rake Only	29 dumps	29	Worked 5 grid section and tried new rock picker. Have to get lights and cameras.
9/16/2003	15:41	0:00	8.3	Surf Rake Only	26 dumps	26	Put lights and cameras on ARTS #2 rock picker. Tried two runs on grid n-32. Lowered upper drum; still not picking up all frag. Wind was blowing about 35-40 miles. Could not work on rock picker. Completed 126' with ARTS #1, installed GPS on ARTS #1. Could not get GPS or sensors to come up; it gave me a green light that it was connected but no info.
9/17/2003	15:20	0:00	8.6	Surf Rake Only	25 dumps	25	Changed 30 tines on ARTS #1 surf rake. Adjusted rollers on ARTS #2 rock picker. Found that need more wiring for valves to work. 123' completed.
9/18/2003	15:35	0:13	8.7	Surf Rake Only	26 dumps	26	Had welder come out and install teeth on lower roller of rock picker ARTS #2. Will install solenoid box and rubber strips on roller tomorrow. Had video problem; turned AC switch on, video cleared up. Completed 125'.
9/19/2003	15:10	0:00	8.9	Surf Rake & Rock Picker	28 dumps	28	Started using rock picker during the day. Didn't have enough light to run at night. Unit is picking up about 90% of the frag. Started adjusting roller gap. Also installed two rubber strips on top drum. This is picking up more stuff. Completed the 5 grid row that we started on 9/12/2003.
9/22/2003	15:35	23:00	7.5	Surf Rake & Rock Picker	32 dumps	32	Installed lights on new art and replaced one light on old ARTS. Adjusted chains on conveyor cylinders. Will see if this keeps it out of the dirt. Completed 140' on grids n-30 o-30 p-30 and 190' on grid n-32. Adjusted rock picker so it is only digging about 1" to 1/2". Cleaned up piles from surf rake; it was picking up a lot of dirt.

Note							When running rock picker you have to line up on grid, turn lift to float start pto, then start upper drum. Have unit in slow speed at end of row before turning turn pto off and float off, raise conveyor do a slow turn.
9/23/2003	15:35	0:00	8.5	Surf Rake & Rock Picker		27	Had a flat tire on ARTS #2 rock picker. Plugged and restarted. Put a 3" pipe behind picker so it would flatten out grid. Working well. Moved up 1 grid. ATI said that n-o-p- 30 grids are clean enough. We should not do them so we moved to n-o-p- 31 20:15 v-17. pto went out. Completed 274' in grid o-32. 256' left to do.
9/24/2003	15:45	0:00	8.3	Surf Rake Only	36 dumps	36	Put t-4 to surf rake. Started back on grids n-o-p-31. Tried magnet for Brian. Completed 170'.
9/25/2003	15:40	0:15	8.5	Surf Rake Only	54 dumps	54	19:20 fueled ARTS. Still in grids n-o-p-31. Sped up ARTS. We are getting more completed. Semi trailer has a rear axel seal leaking; taking it to Reno to have it repaired. Completed 256'.
9/26/2003	15:00	0:20	9.4	Surf Rake Only	62 dumps	62	Took truck to shop; having rear axel and boards replaced. Completed 314'. Ran ARTS at full speed; still picking up a lot of frag. Completed grids n-o-p-31.
9/29/2003	12:53	0:00	11.1	Surf Rake Only	81 dumps	81	We started early in grids o-p-32. The ATI personnel had to leave area due to sand storms and 30 mph winds. Fueled ARTS at 17:00. Unit is burning about 2.25 gallons per hour. Towing the surf rake. Completed 820' of these grids. Ops is complete. We will load equipment tomorrow and fly home.
9/302003							Loaded equipment for shipment to Panama City.

Appendix G

Equipment Manufacturers & Cost

Item	Manufacturer	Purchase Cost
ARTS	ASV Inc. 840 Lilly Lane Grand Rapids, MN 55744 (800) 346-5954	$175,000
Barber Surf Rake 600HD	H. Barber & Sons, Inc. 15 Raytkwich Drive Naugatuck, CT USA 06770 (203) 729-9000	$ 46,000
Harley Power Rake M8	Glenmac Inc. PO Box 2135 Jamestown, ND 58402-2135 (800) 437-9779	$ 8,677
Shields 5000 Magnet 5’	Shields Company P.O. Box 1572 Ventura, CA 93002 (800) 799-4408	$ 5,410
Harley Rock Picker B	Glenmac Inc. PO Box 2135 Jamestown, ND 58402-2135 (800) 437-9779	$ 34,000

Appendix H

Project Costs

Month	Operating Expenses (Fuel, Supplies, Support Vehicles)	Labor	Travel (Per Diem, Lodging, Air Fare)	Shipping	**Sub Total**
July	$ 4,857.40	$ 26,177.58	$ 8,458.48	$ 4,470.00	$ 38,812.14
August	$ 5,412.16	$ 32,825.69	$ 11,409.84		$ 43,171.91
September	$ 7,867.73	$ 56,772.46	$ 15,205.24		$ 69,430.81
October		$ 2,590.42		$ 6,286.47	$ 8,539.01
	$ 18,137.29	$ 118,366.15	$ 35,073.56	$ 10,756.47	$ 182,333.48